DESIGN OF AN INTERFEROMETRIC TEST STATION FOR PARALLEL INSPECTION OF MEMS

C. Schaeffel(1), S. Michael(1), R. Paris(1), A. Frank(1), N. Zeike(1), K. Gastinger(2), M. Kujawinska(3), U. Zeitner(4), S. Beer(5)

(1) IMMS Institut für Mikroelektronik- u. Mechatronik Systeme, Ehrenbergstr. 27, D-98693 Ilmenau, Germany
(2) NTNU Trondheim, before SINTEF IKT Optical measurement systems and data analysis N-7465 Trondheim, Norway,
(3) Institute of Micromechanics and Photonics, Warsaw University of Technology, 8 Sw. A. Boboli St.,Pl-02-525 Warsaw, Poland
(4) Fraunhofer IOF, A.-Einstein-Str. 7, 07745 Jena, Germany
(5) CSEM Centre Suisse d'Electronique et de Microtechnique SA, Technoparkstr. 1, CH-8005 Zurich, Switzerland

ABSTRACT

The paper presents the optical, mechanical, and electro-optical design of an interferometric inspection system for massive parallel inspection of Micro-Electro-Mechanical-Systems (MEMS) and Micro-Opto-Electro-Mechanical-Systems (MOEMS). The basic idea is to adapt a micro-optical probing wafer to the M(O)EMS wafer under test. The probing wafer is exchangeable and contains a micro-optical interferometer array. A low coherent and a laser interferometer array are developed.
Two interferometer designs are presented; a low coherent interferometer array based on a Mirau configuration and a laser interferometer array based on a Twyman-Green configuration. The smart-pixel approach for massive parallel electro-optical detection and data reduction is discussed.
The mechanical design concentrates on the scanning system and the integration in a standard test station for micro-fabrication. First experimental results of a test scanning platform are presented. The overall control concept is described.

1. INTRODUCTION

Reduced costs and enhanced reliability are essential for the further growth of the M(O)EMS market. This requires tests on wafer-level during production to detect faulty sensors before the subsequent packaging and assembly steps. Non-electrical parameters of M(O)EMS like shape, deformation or modal frequencies are usually measured by interferometry. Currently, commercial optical test systems do measurements serially, which causes large measurement time and costs. Hence the concept of the test system to be developed within the EU project SMARTIEHS pursues the parallel measurement of multiple dies [1] to obtain a significant reduction of measurement time.

2. INSPECTION CONCEPT

The parallel testing is realized by an exchangeable micro-optical probing wafer, which is adapted and aligned with the M(O)EMS wafer under test. The probing wafer comprises an interferometer array, which configuration, spacing and resolution depends on the M(O)EMS object. The corresponding illumination, imaging and excitation unit are modular and can be adapted and optimized for specific devices.
The demonstrator under construction uses a 5x5 interferometer array processed by standard micro-fabrication technologies. The multi-functionality of the system is given by two different probing wafer configurations, a 5x5

array of low coherent interferometers (LCI) and a 5x5 array of laser interferometers (LI). An array of 5x5 smart-pixel cameras is designed for the detection of the interferometer signals. The cameras feature optical lock-in detection at the pixel level [2].
Figure 1 shows a sketch of the probe system with the integrated inspection system.
The configuration of the two different interferometer arrays is shown in Figure 2. The left side of the image shows the low coherent interferometer array (Mirau) and the right side the laser interferometer array (Twyman-Green). The light sources are arranged in an array and positioned on each side of each interferometer unit. The light is guided by a beam splitter towards the probing wafer.

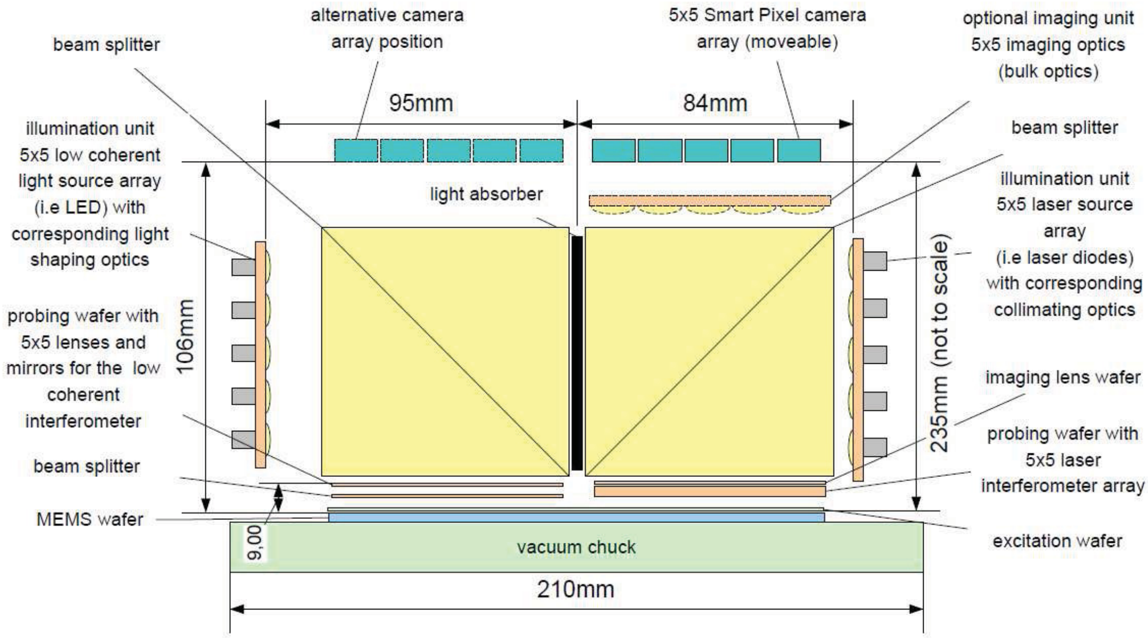
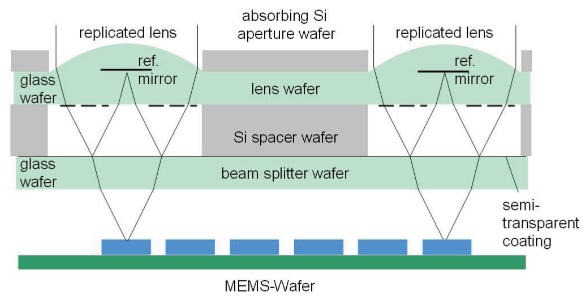
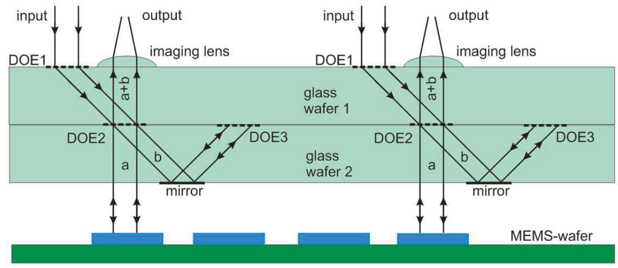


Figure 1: SMARTIEHS instrument configuration: Side view with dimensions.

The interference signals are generated in the micro-optical interferometers, which are fabricated in a regular matrix on a 4-inch wafer stack.
The refractive design (
Figure **2**a) will be used to measure the shape and deformation, the diffractive design (
Figure **2**b) will be applied for vibration analysis.





a) low coherent Mirau interferometer

b) laser Twyman-Green interferometer

Figure 2: Preliminary interferometer design

An excitation system for the passive M(O)EMS structures is needed for dynamic testing. A glass wafer consisting of Indium Tin Oxide (ITO) electrodes is applied for electrostatic excitation of the resonance frequency of the structures [3]. For the deformation measurements a tailor made pressure chuck is used.

3. SMART-PIXEL CAMERA DESIGN

Figure 3 shows the configuration of the imager array camera. The smart-pixel imagers are placed in a 5x5 matrix at the camera module which transfers the images via a high speed frame grabber to the PC. The pitch between the imager chips is adapted to the interferometer pitch.

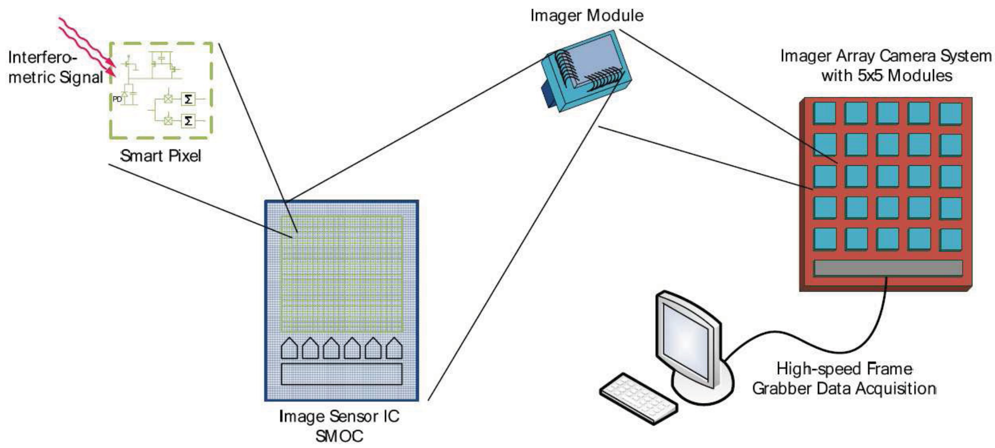


Figure 3: Configuration of the smart-pixel camera

Each channel is equipped with a smart-pixel CMOS imager for detection of the optical signal. Every imager features 140×140 pixels. The developed smart-pixel architecture allows the demodulation of the electro-optical signal at the detection level with demodulation frequencies up to 100 kHz.

The demodulated signal is averaged over a few periods and then read out to the control system, which leads to a drastic data volume reduction on the one hand and an increasing depth scan speed on the other hand. The electronic circuit at the pixel level does not only allow amplitude demodulation but also the extraction of the modulation phase and is well suited for use with LCI and LI interferometry.

4. SCANNING DRIVE DESIGN

A high-precision drive unit is needed for focusing the measurement interferometer towards the M(O)EMS devices in z-direction. Furthermore, the z-drive has to realize a highly uniform movement of the optical system with respect to the low coherence measurements. LCI requires a scan over a range of 1mm with a linearity of < 1%. LI requires positioning accuracies with a measurement error < 10nm and a position stability in the nanometer range. Therefore, the design concept integrates three voice-coil drives and three commercial interferometers to move and align the scanning platform relative to the MEMS-Wafer.

Besides the z-scan the platform enables pitch and roll motions for the parallel alignment of the interferometer array to the MEMS-wafer. To realize a straight-lined and uniform z-motion the platform is weight compensated by pull-springs and guided with star-shaped leaf springs, which provide a ratio of horizontal to vertical stiffness of over 10000. The nonlinearity of the leaf springs stiffness is compensated by feed forward control.

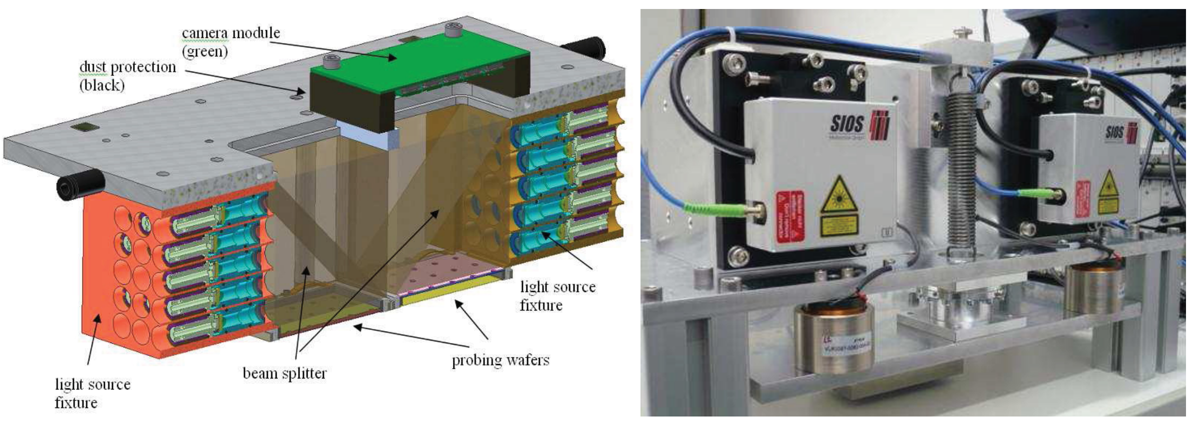


Figure 4: Optical unit with LCI and LI (left); Test setup of scanning platform (right)

5. CONTROLLER DESIGN

The controller of the platform runs on an IPC board, using RTAI Linux as real time operating system. It is connected to the hardware via an I/O board, which preprocesses the analogue signals. The platform position is measured by three laser interferometers whose measuring beams are coaxial arranged to the three voice coils. The analogue signals provided by the interferometers are interpolated by an FPGA. As the platform has to be adjusted by tilting moves (pitch and roll) before each measurement, the overall functionality of the controller is designed for separate tilting and traversing (z-scan) motions.
While a setpoint generator for one-dimensional motions provides position, velocity and acceleration values for traversing in real-time, setpoints for tilting angles are set up by an independent method.
Since the movement of the three axes is strongly coupled on account of the overall geometry, it is desirable to decouple them calculationally in order to allow controlling the position of each voice coil. This decoupling is implemented in the controller by transformations of coordinates and conversions of forces so that the coil currents provide the forces necessary for the desired motions.

6. CONCLUSIONS

The presented inspection system concept realizes a parallel approach for the production test of up to 100 M(O)EMS objects simultaneously. A multifunctional approach is implemented by the modular design including the micro-fabricated interchangeable interferometer wafer systems – static as well as dynamic measurements can be performed. Correspondingly, two different micro-optical interferometer configurations are presented; a Mirau type low coherent interferometer for shape and deformation measurements and a Twyman-Green type laser interferometer for the measurement of resonance frequency and the spatial vibration mode distribution.
A novel distributed smart-pixel camera is developed. It consists of a 5x5 matrix of smart-pixel imager. Each imager has a 140x140 pixel resolution giving a total number of almost half a million interferometer channels. The smart-pixel approach enables "on pixel" demodulation of the interference signal and thus contributes to data reduction and a short measuring time.
The project is now focused on the production of the designed submodules and the integration into the demonstrator in order to validate the concept with the specified parameters.

Acknowledgement

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7. REFERENCES:

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